BAE SYSTEMS

Collaborative Signal Processing for Sensor Networks

Stephen R. Blatt
stephen.r.blatt@baesystems.com
BAE SYSTEMS
Nashua, NH

This material is based upon work supported by the Space and Naval Warfare Systems Center - San Diego and DARPA/IXO under Contract No. N66001-00-C-8054

BAE SYSTEMS

BAE SYSTEMS/MIT Collaborative Signal Processing Tasks

- **Networked Tracking - BAE SYSTEMS**
  - **improve data association between nodes**
- **Distributed Network Processing - MIT**
  - **lower field power requirements**

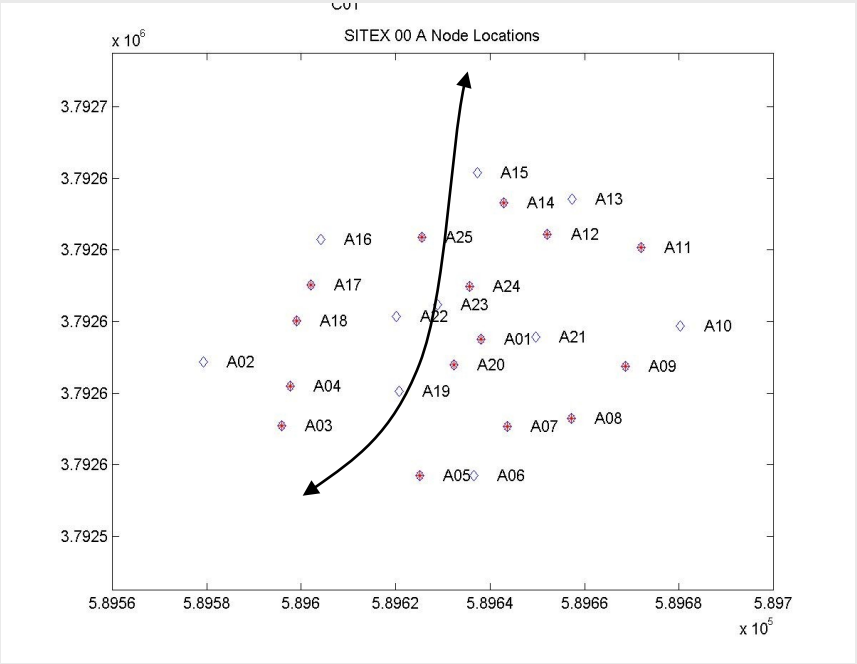
BAE SYSTEMS

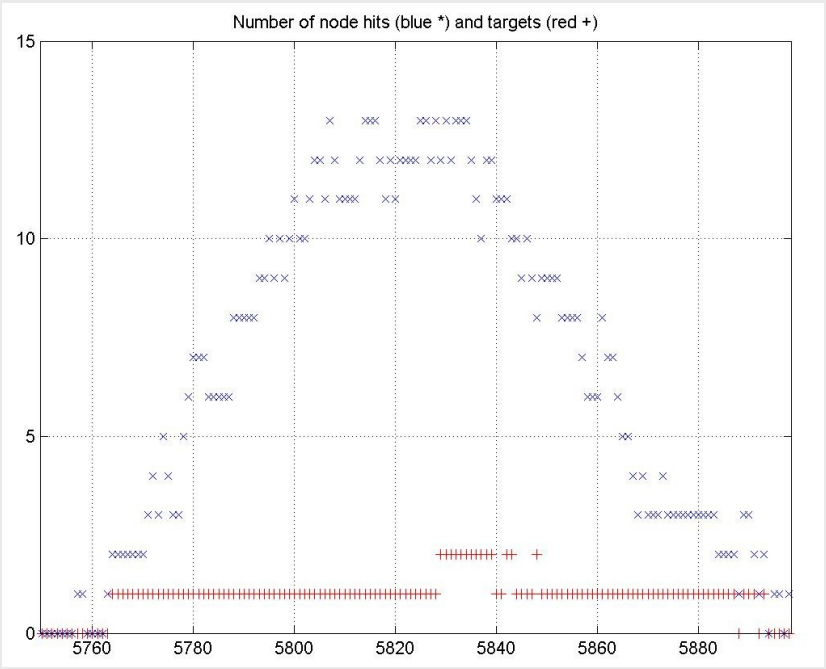
Agenda

- Algorithm
- SITEX 02 Data Collection
- Results of data analysis to date
  - Tripwire algorithm
  - Personnel detection
- Future plans

BAE SYSTEMS

Sensor system must reduce multiple node data to single output

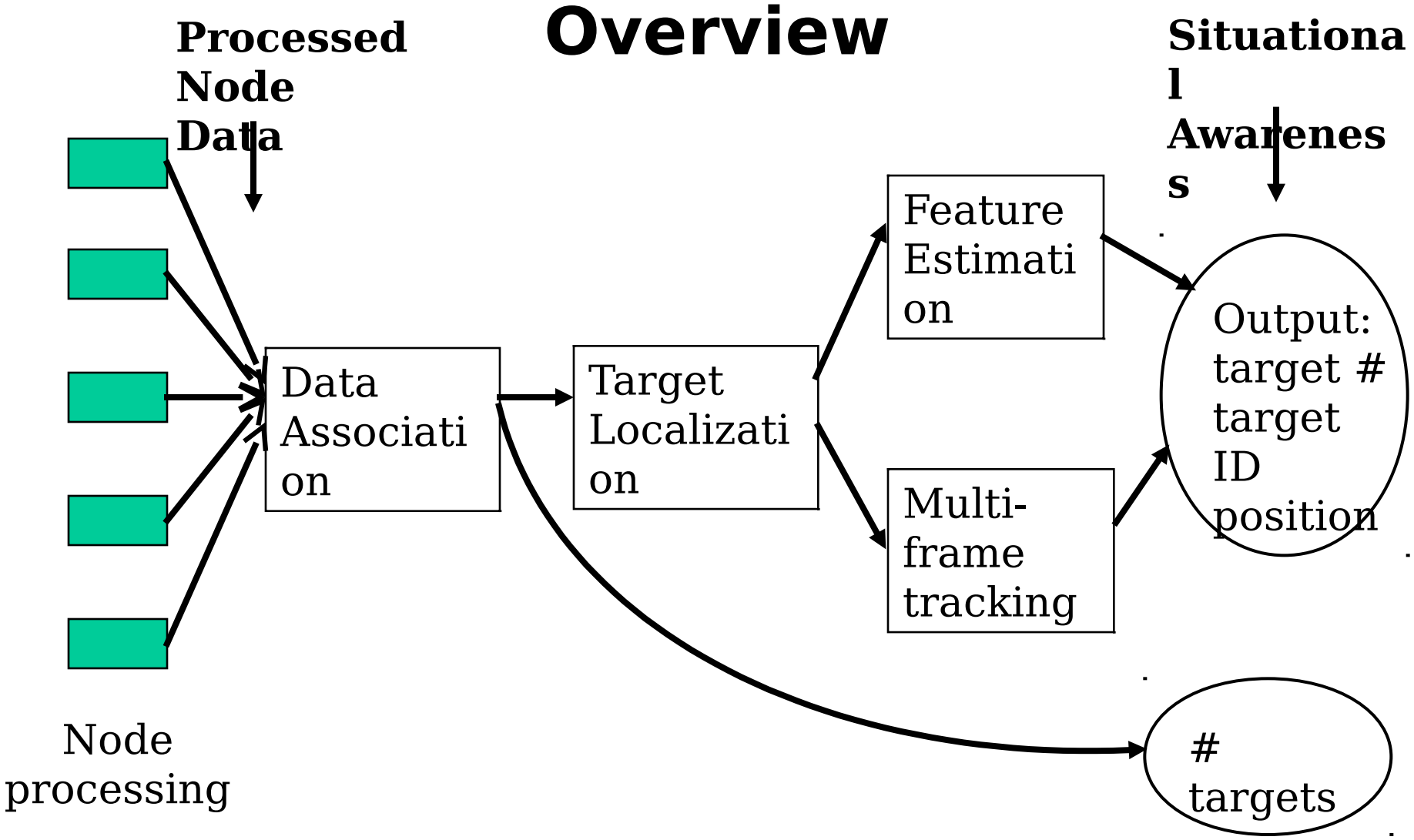




- **Two vehicles passing through 13 node cluster**

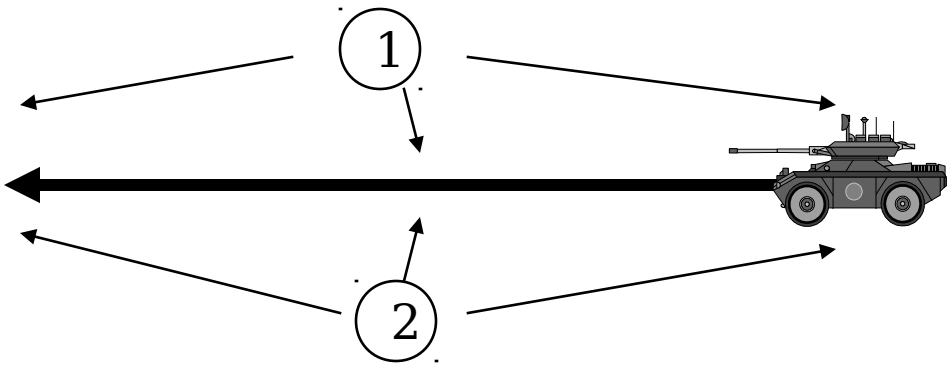
BAE SYSTEMS

Situational Awareness Processing Overview

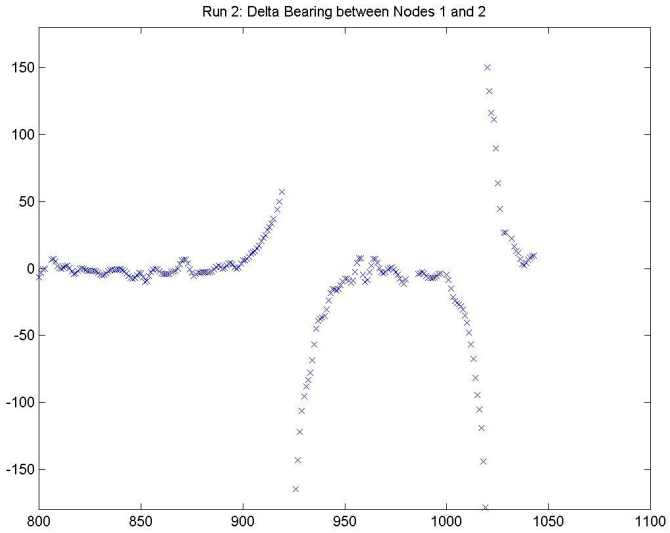


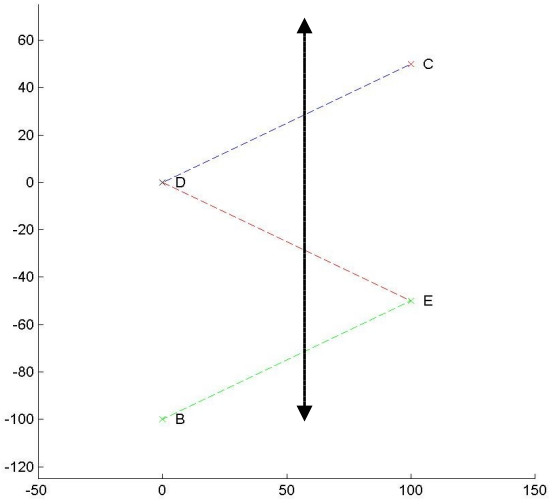
BAE SYSTEMS

Data Association Using Tripwire



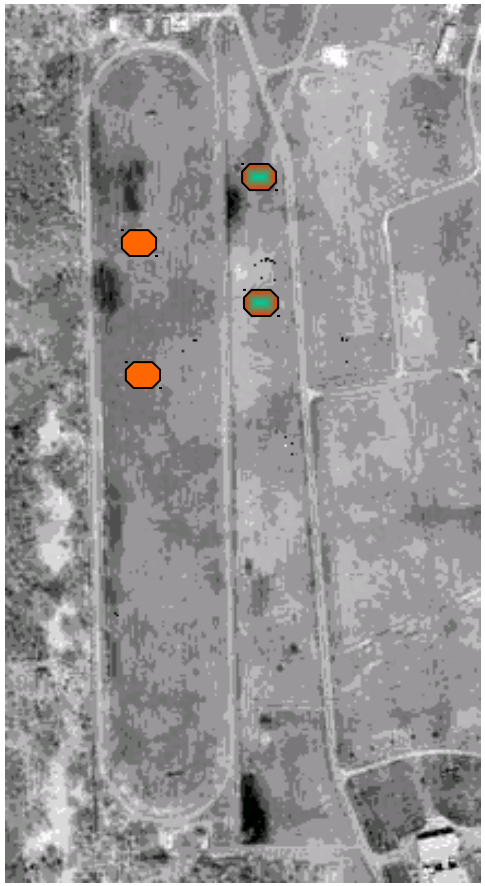
- From tripwire nodes, bearing to target is same at infinity, and opposite at crossing
- Can resolve multiple targets
- Estimate position between nodes based on size of bearing difference

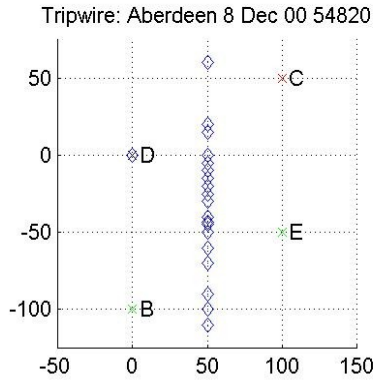


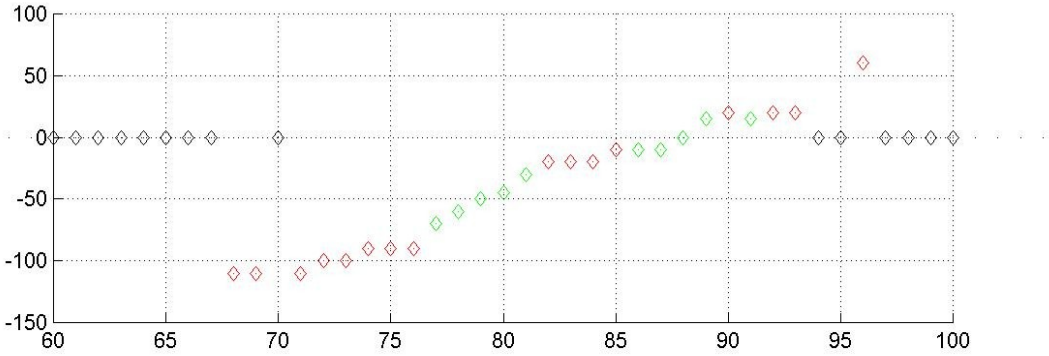


BAE SYSTEMS

Aberdeen Dec 00 Tripwire



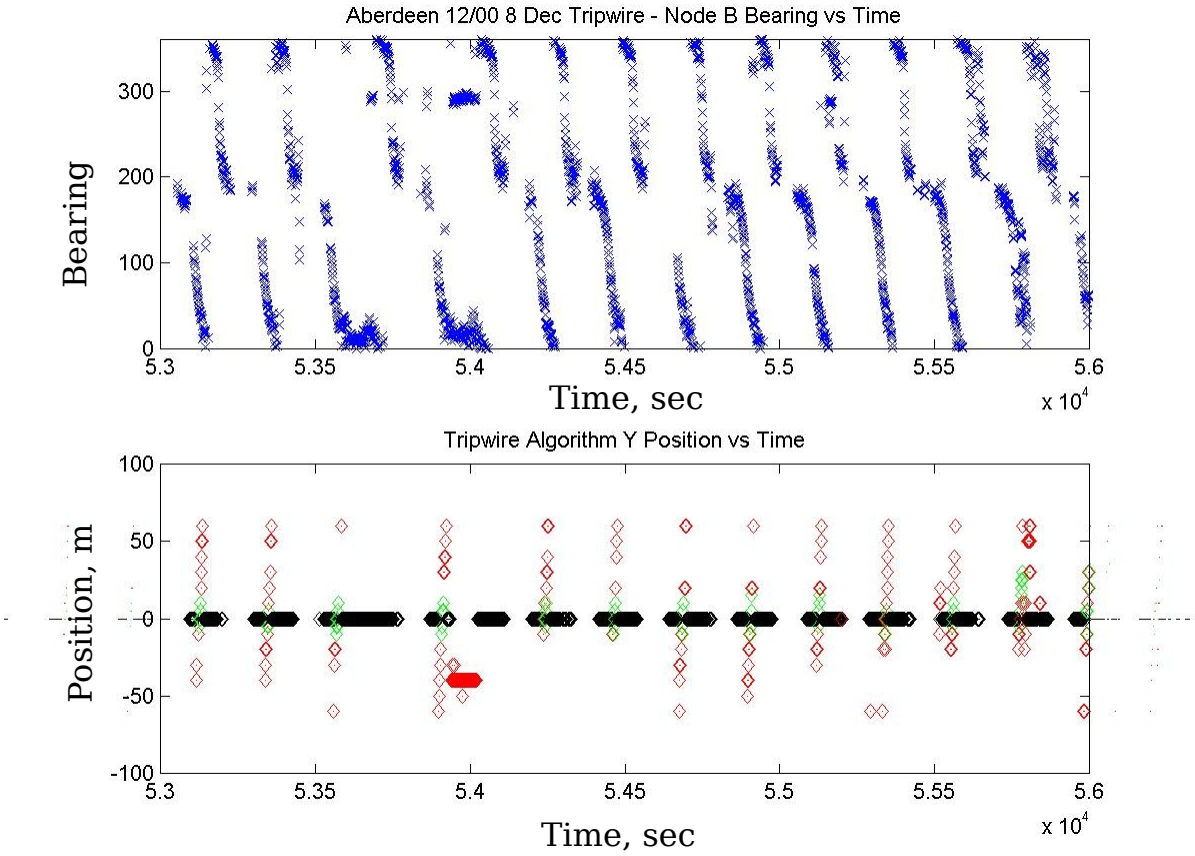




- **Diamond configuration**
  - **100m spacing each axis**

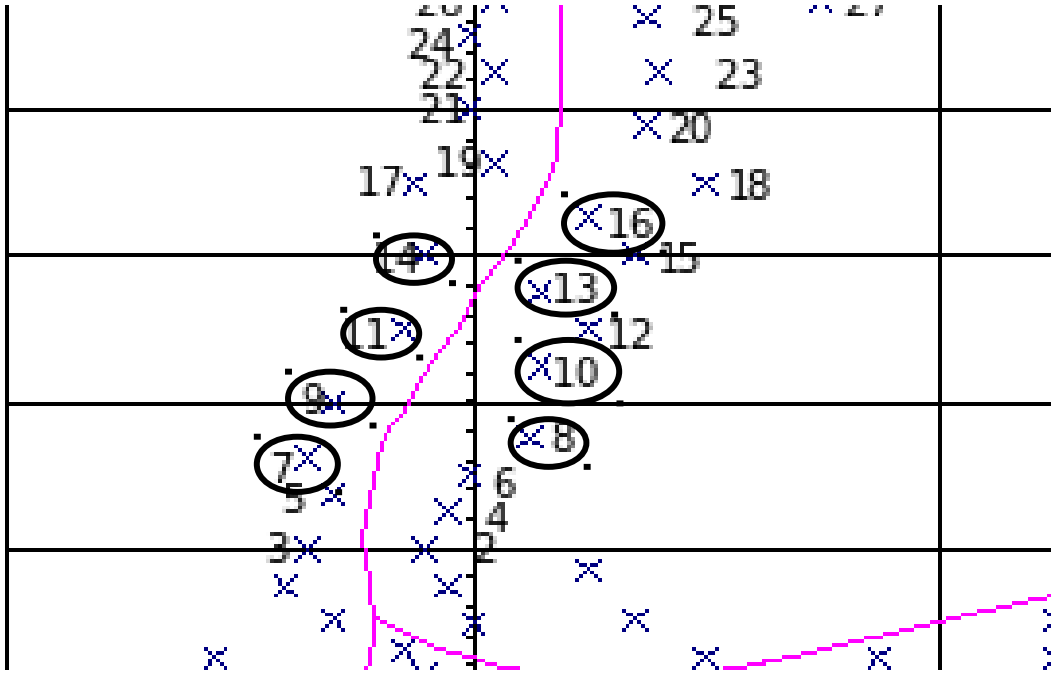
BAE SYSTEMS

Example over 13 transits



BAE SYSTEMS

SITEX 02 Node Locations

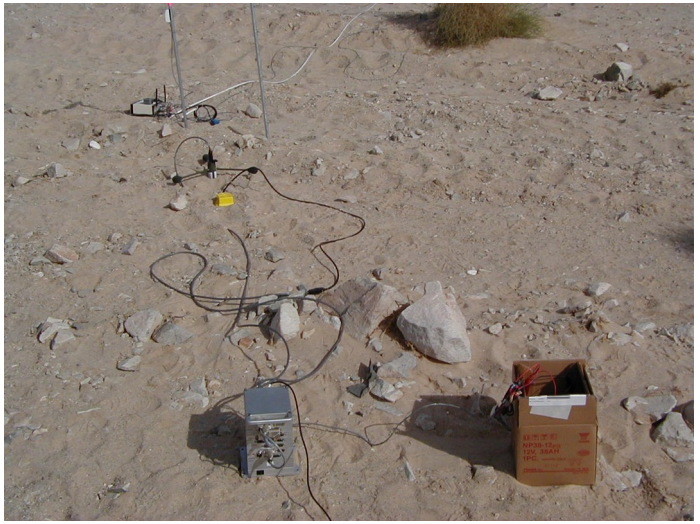


- **12 thru 14 November**
- **Nodes 7, 8, 9, 10, 11, 13, 14, 16**
- **Average Node Separation = 41.6m**

BAE SYSTEMS

BAE SYSTEMS Sensor System

- 3 microphone array
- 1-axis or 3-axis seismic array
- a/d, fs = 1024 Hz
- on-node processing & storage



- fusion on gateway node

BAE SYSTEMS

Software Configuration

MIUGS

Senserv

- calculate bearing
- sends bearing via serial link
- log to file

RS-232

WINS 2.0

BearingServer

- puts data into twrec repository

BearingClient

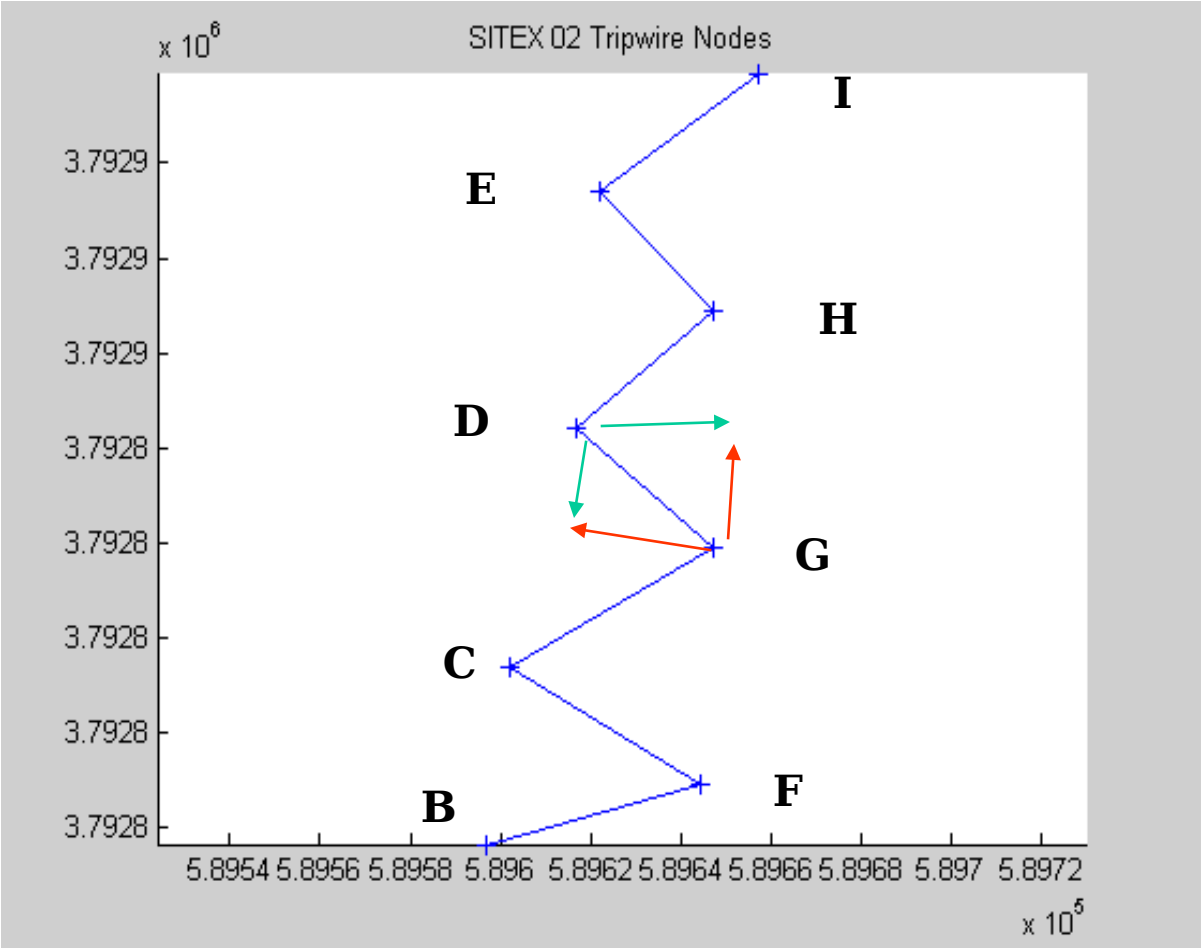
- get twrec data, publishes via diffusion
- logs to local file

Tripwire

- subscribes to all nodes
- logs all bearings to file
- run tripwire
- logs positions to file
- outputs data

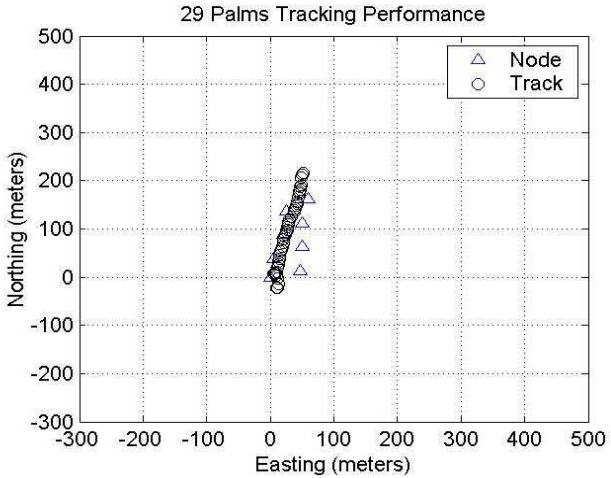
BAE SYSTEMS

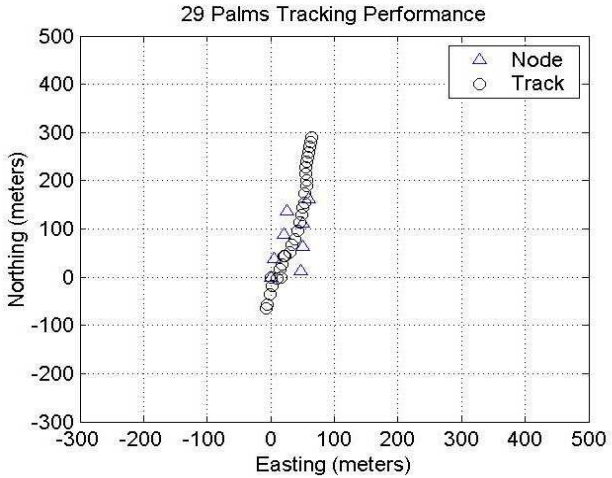
Node Pairs and Gates

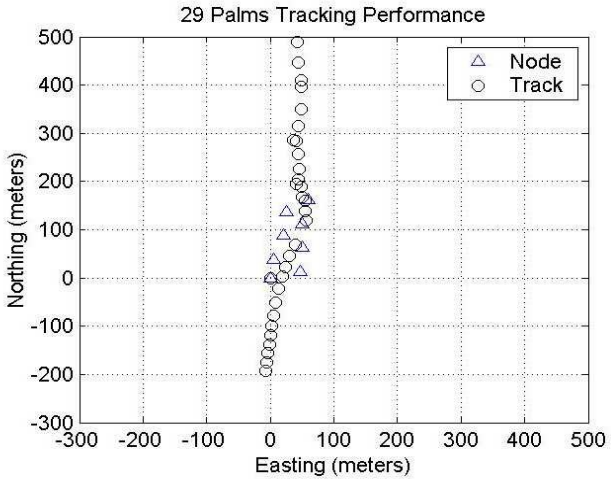


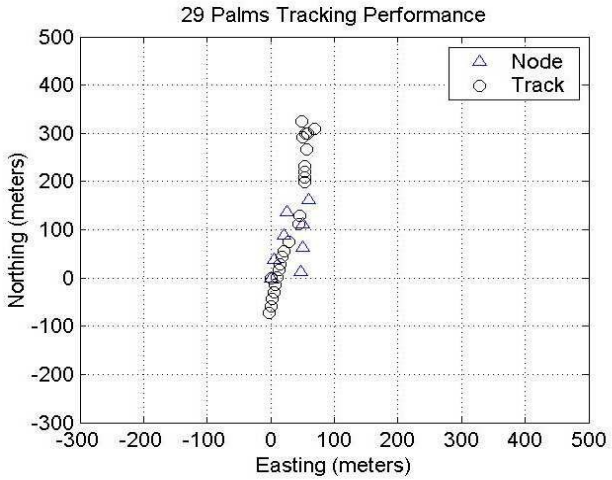
Tracking results: baseline system

BAE SYSTEMS







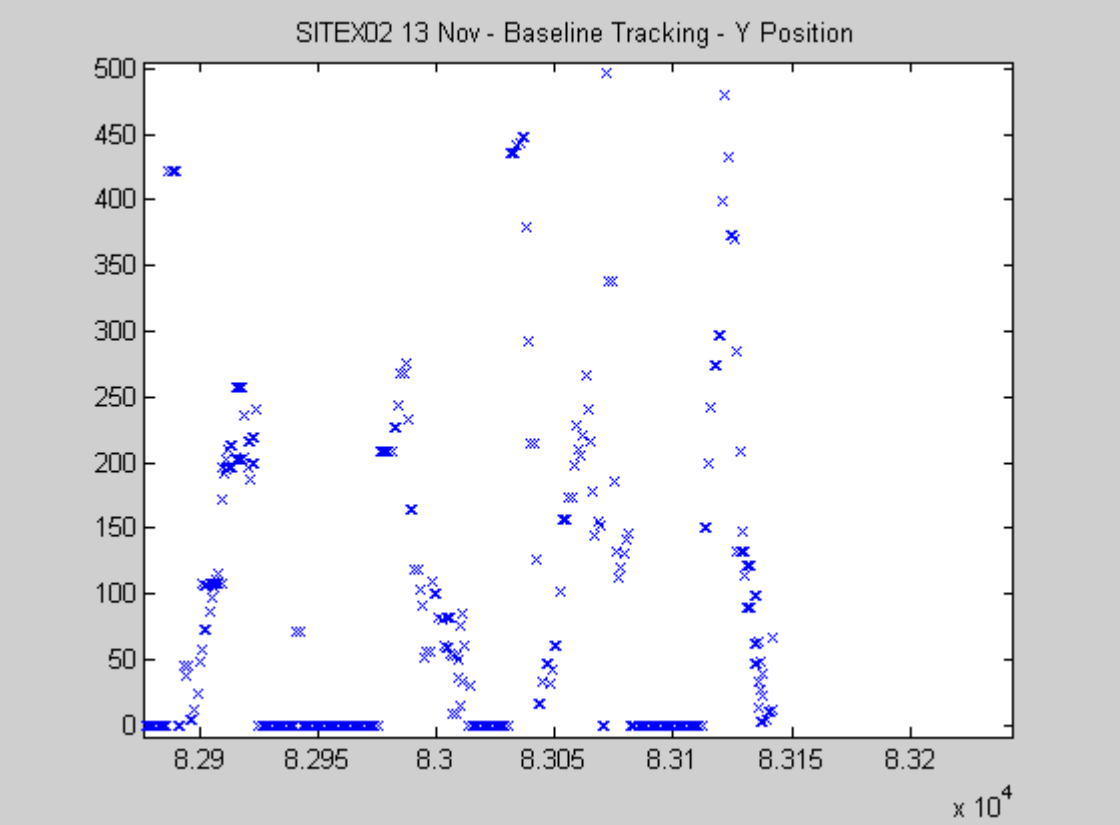


14 Nov, > 2300 GMT

Tracking results - baseline system

BAE SYSTEMS

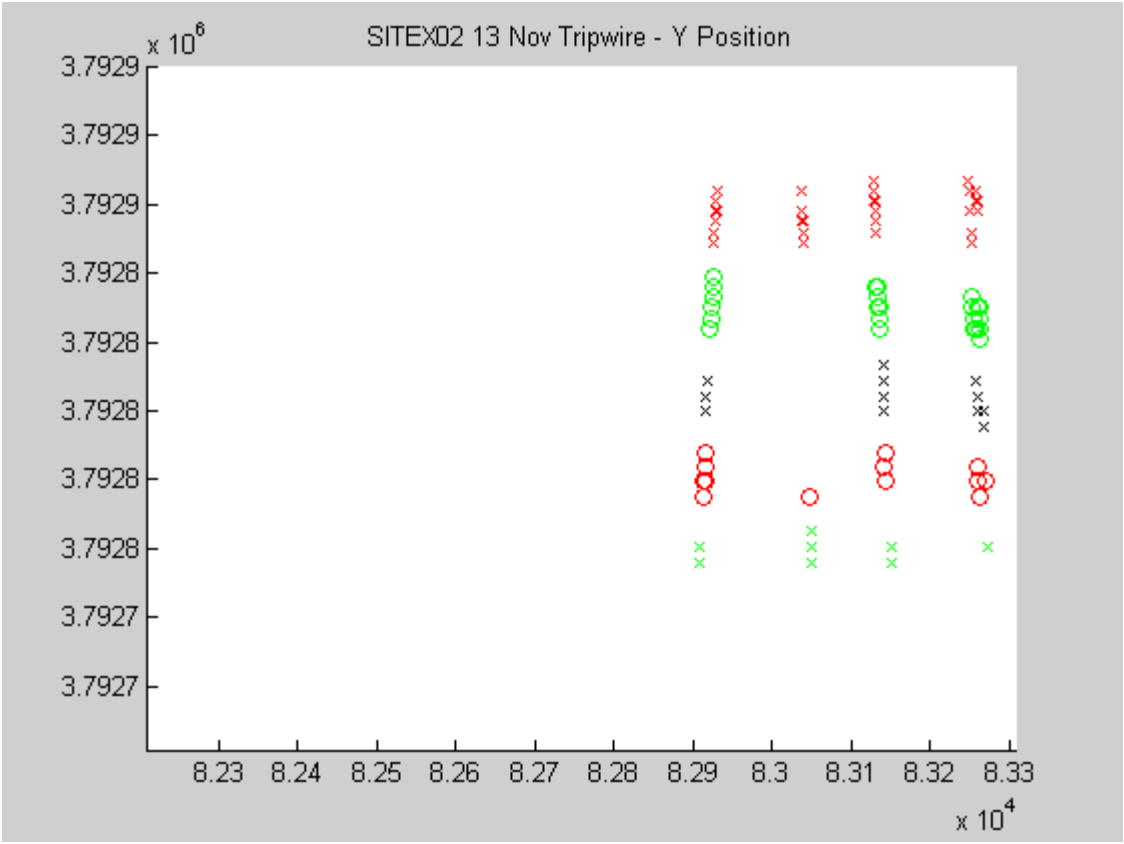
Y, m



Time, seconds

BAE SYSTEMS

Tracking results - Tripwire



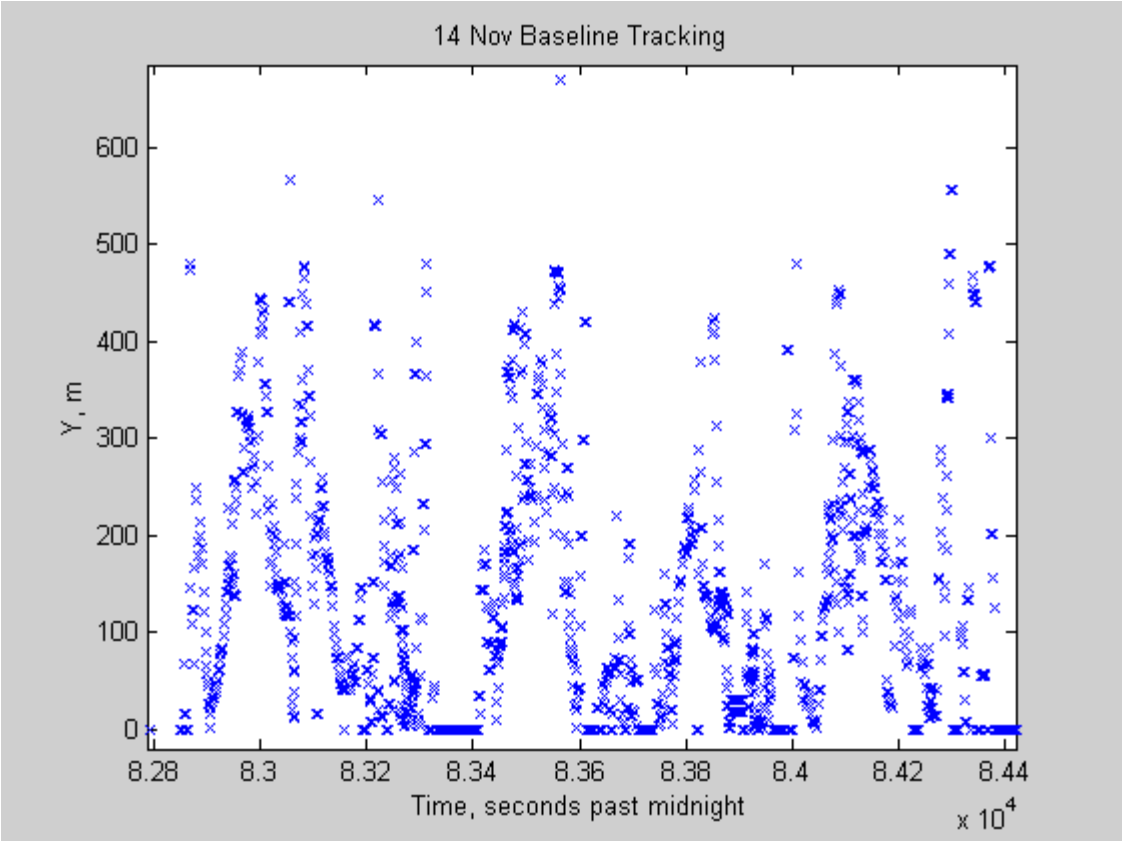
Y, m

Time, seconds

BAE SYSTEMS

Multiple Single Vehicle Passes - Baseline Tracking

Y position, meters

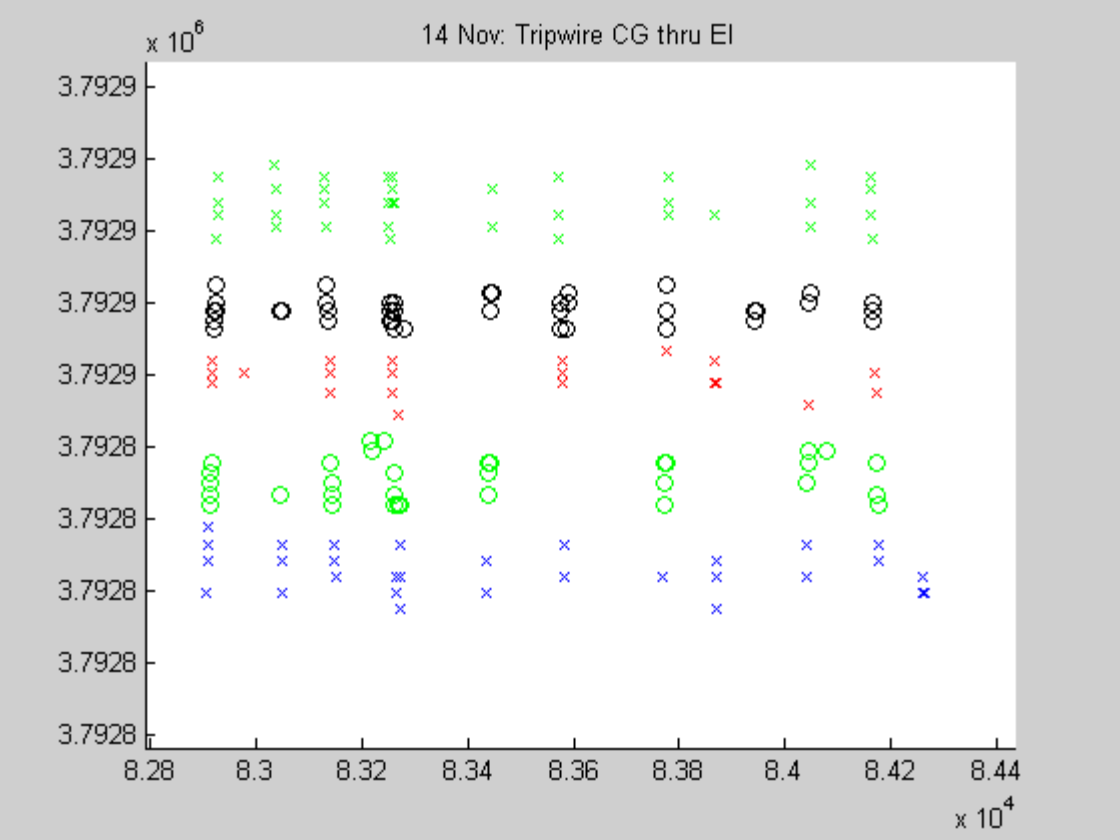


Time, seconds past midnight

BAE SYSTEMS

Multiple Single Vehicle Passes - Tripwire

Y position, meters, 200m span

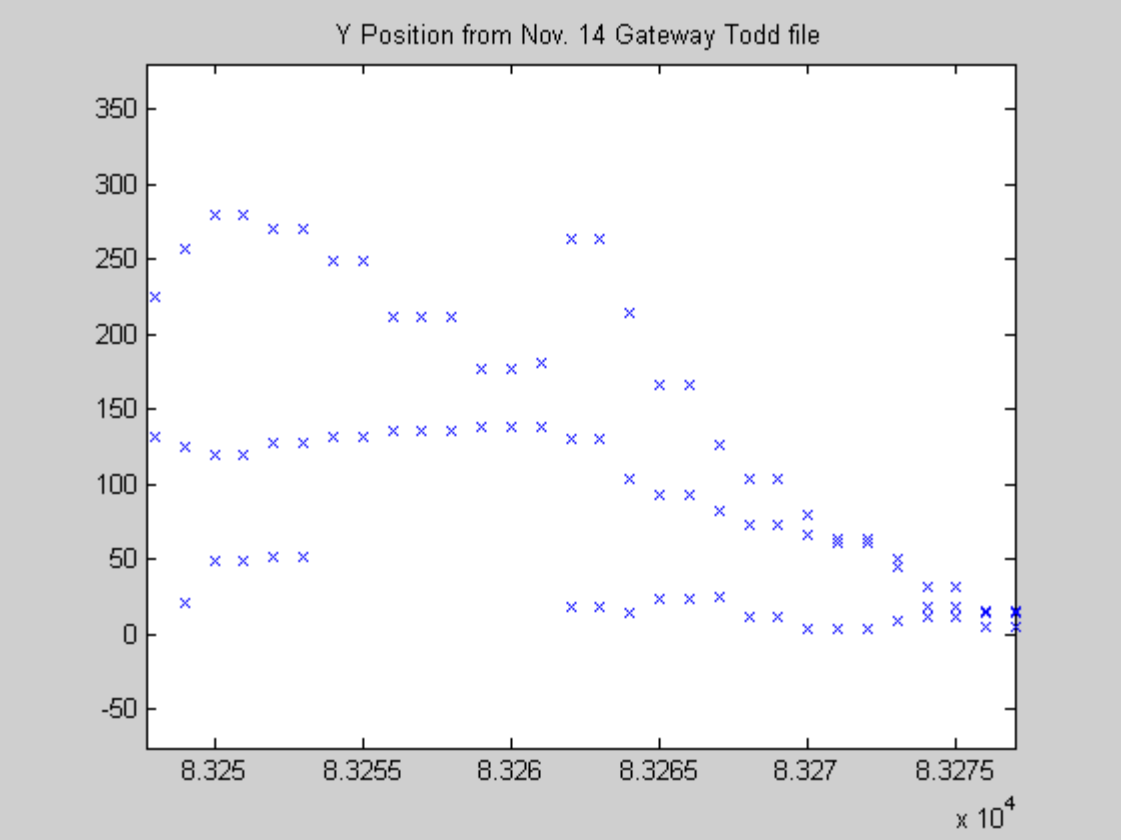


Time, seconds past midnight

BAE SYSTEMS

SITEX 02 Results - Two Targets - Baseline Tracking

Y position, meters (50m per box)

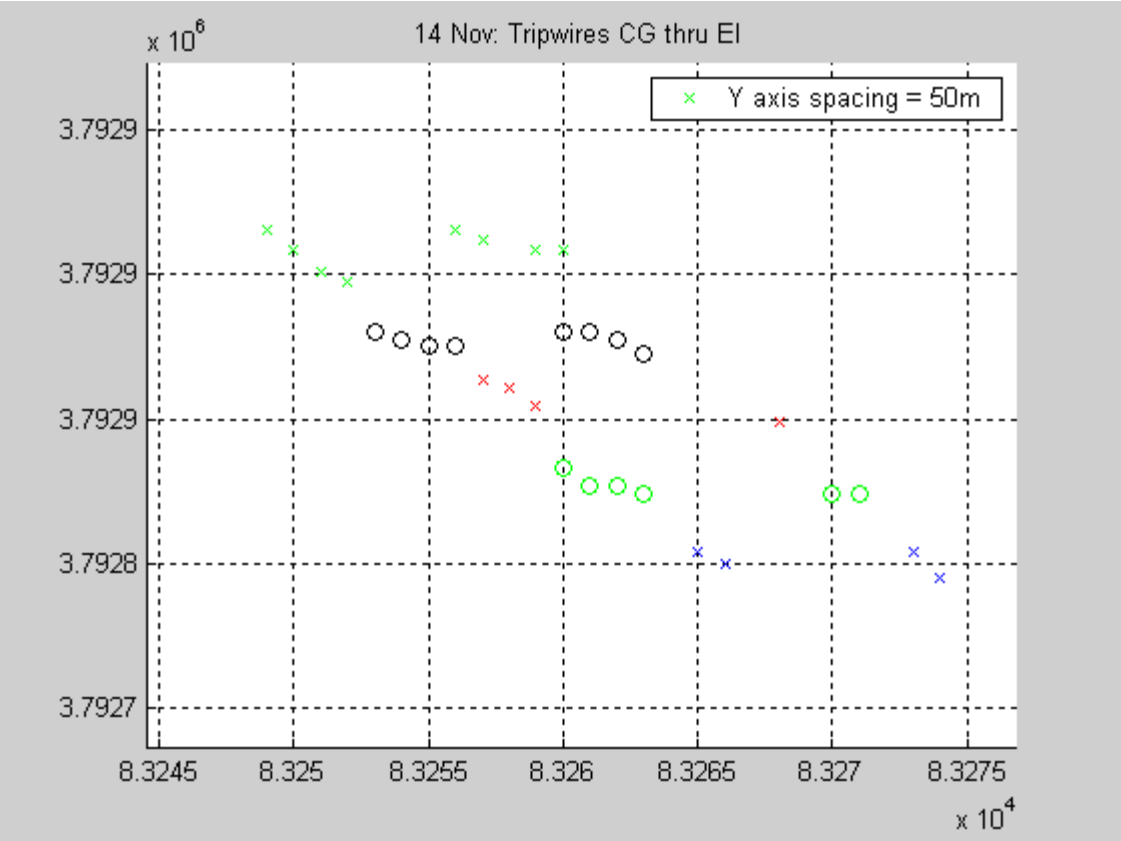


Time, seconds past midnight (5s per box)

SITEX 02 Results - Two Targets Tripwire

BAE SYSTEMS

Y position, meters (50m per box)



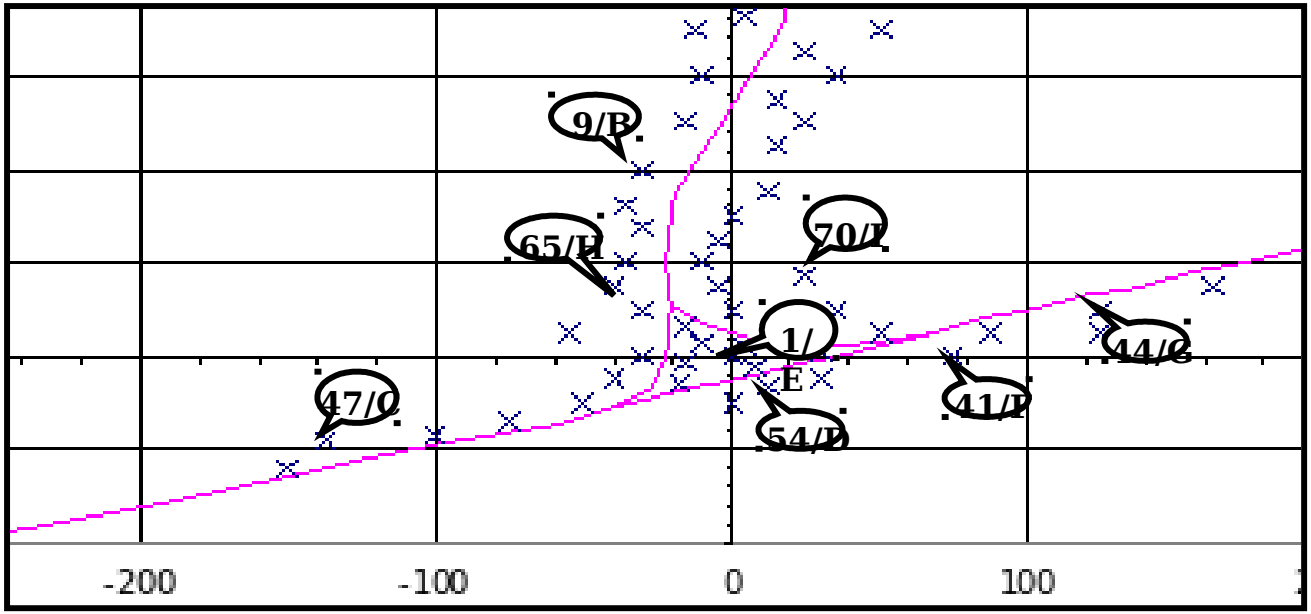
Estimated target separation = 40m - 50m

Time, seconds past midnight (5s per box)

BAE SYSTEMS

Tripwire Analysis Status

- **Analyzing data for 12, 13, 14 Nov**
- **Awaiting log, video, ground truth information**
- **Second configuration for 15 Nov**



Tripwire Algorithm Effectiveness

BAE SYSTEMS

- **Provides accurate position**
- **Provides accurate count for target spacing > node spacing**
- **Low processing requirements on node**
  - **avoids combinatorial explosion (e.g. LOB intersection) since small potential number of targets**
- **Scalable over number of nodes**
  - **one report per target**
- **But**
  - **Dependent on good data from nodes**
  - **Not helpful when target is outside node grid**

BAE SYSTEMS

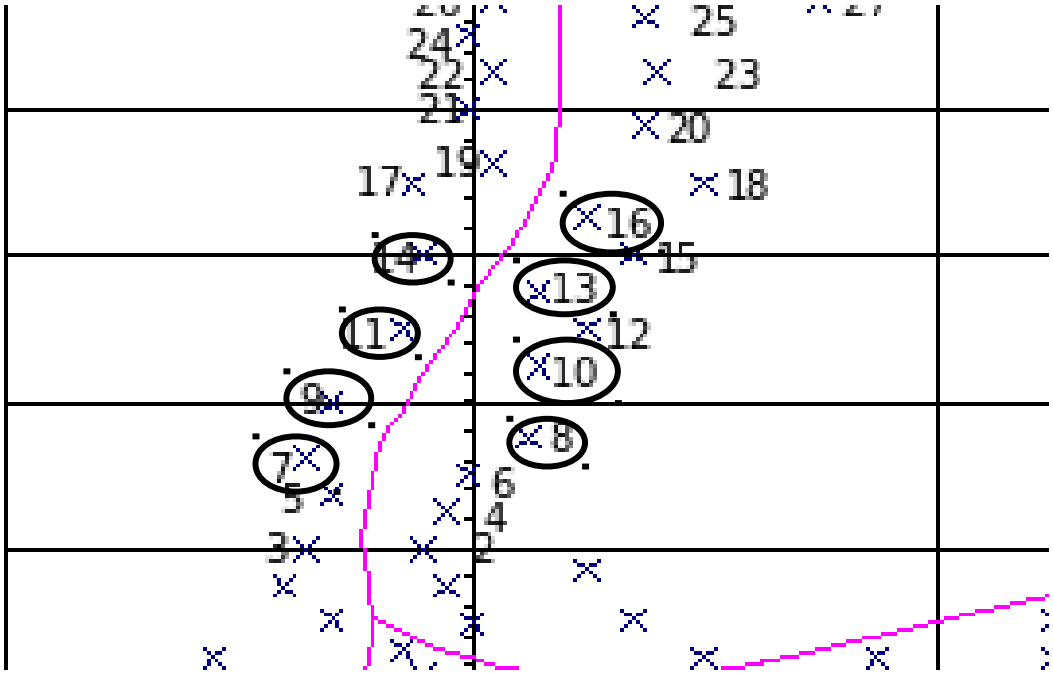
SITEX 02 Personnel Analysis

- **12 Nov - column of 342 Marines**
  - **West to intersection, paused, then went North**

BAE SYSTEMS

Personnel Tracking Set-up

- 3 axis geophones deployed to east of road



H - 13m

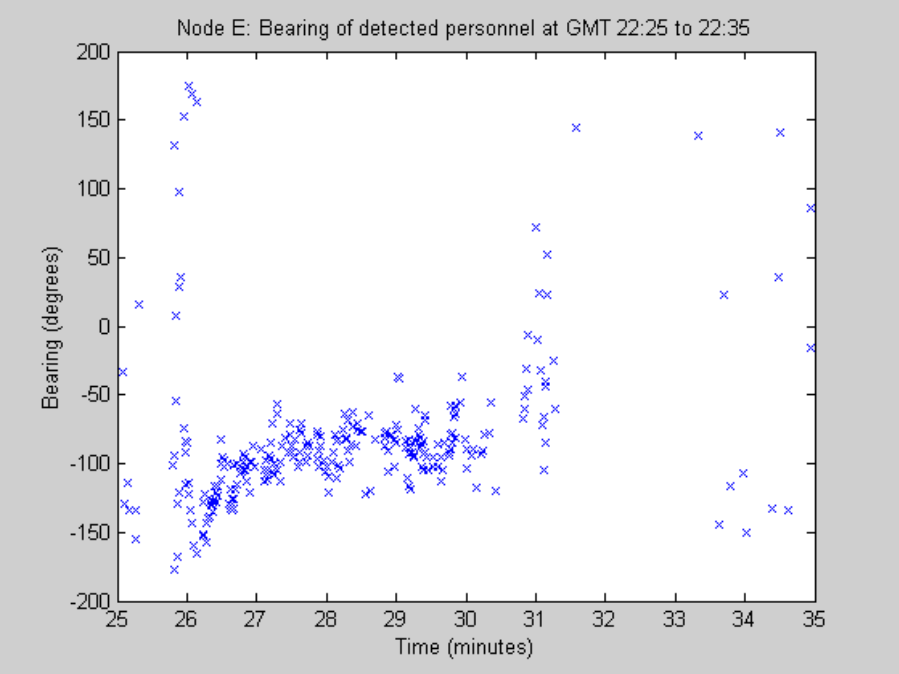
G - 12m

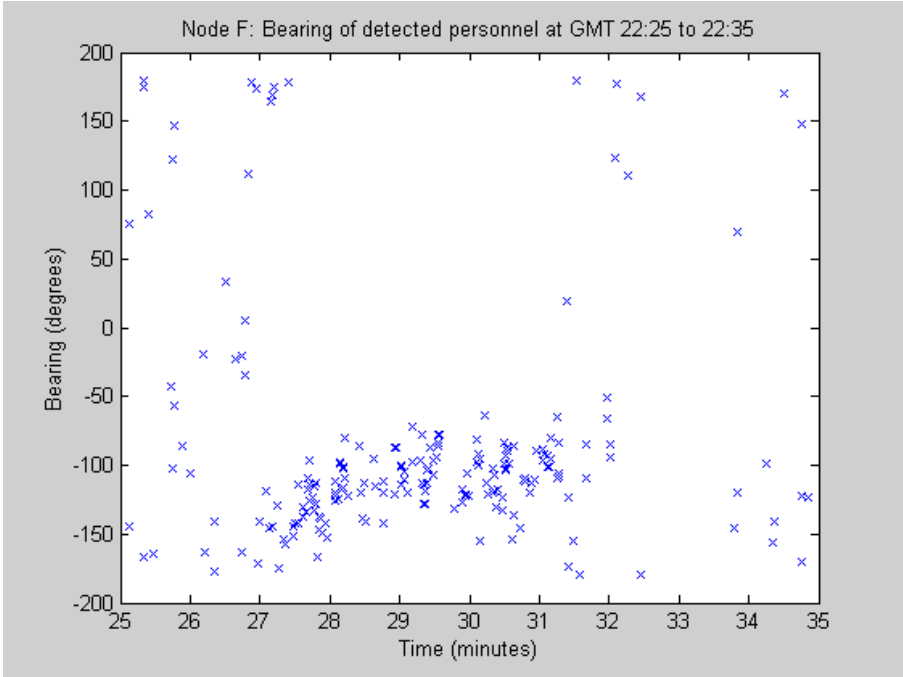
F - 23m

E - 30m

BAE SYSTEMS

SITEX 02 Personnel Analysis

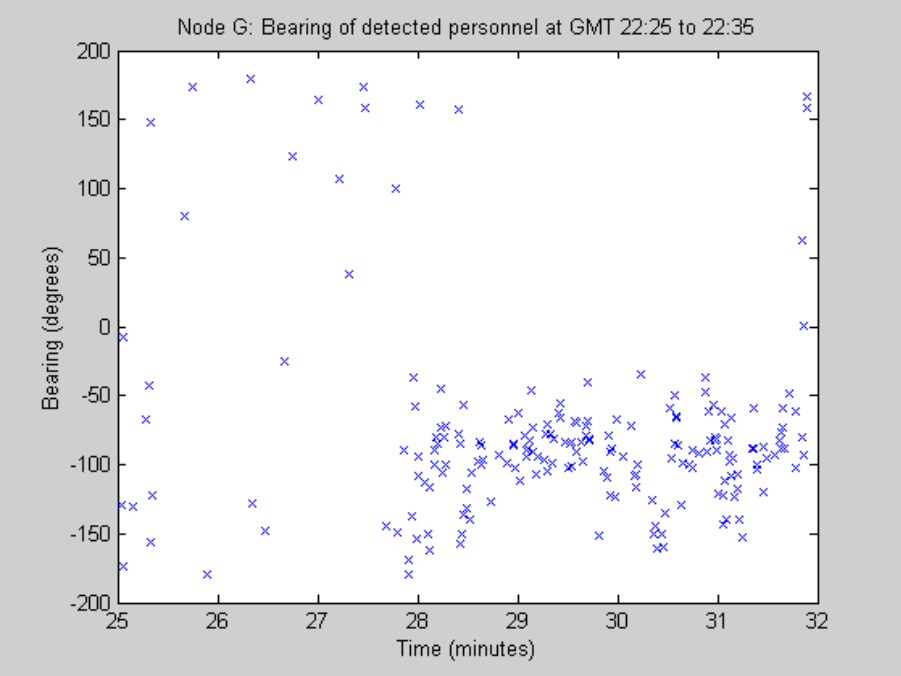


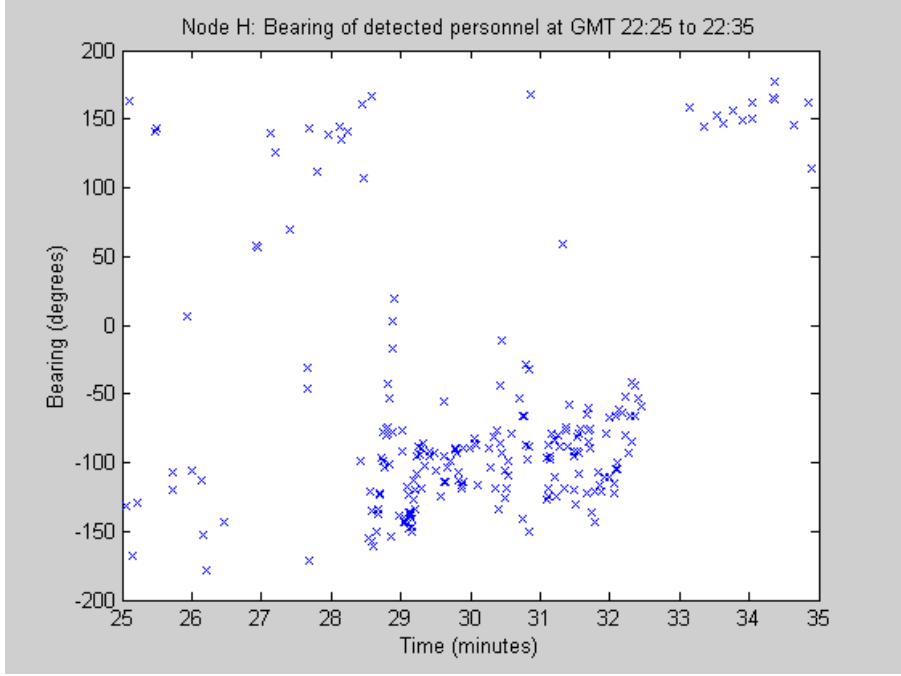


Troops moving SW to NE

BAE SYSTEMS

SITEX 02 Personnel Analysis





BAE SYSTEMS

Future Work

- **Analyze additional SITEX 02 data**
  - **bearing tripwire**
  - **doppler tripwire**
- **Data Quality Evaluation**
  - **comparing data from cooperating nodes to identify nodes with bad data**
- **Cued aerial observer**
  - **UAV or parachute viewer**
  - **photo, targeting**